CHAPTER III

THEORIES OF ENDOGENOUS GROWTH

Economists have developed new theories that address the limitations of the neoclassical theory. The primary contribution of these new theories is that they display steady-state growth in per capita output without relying on exogenous technological change. The models are referred to as endogenous growth models because growth occurs as a result of forces the model explicitly considers. In one sense, these models have made endogenous the technological change that the neoclassical model assumed was exogenous.

Unlike the neoclassical model, many of the models in the literature on endogenous growth provide a framework for analyzing the effects of government policies on economic growth. Based on the models, analysts are able to recommend certain taxing and spending policies and to discourage the use of others. In addition, the models suggest that raising the national saving rate (for example, by lowering the deficit) can raise not only the level but also the rate of growth of per capita output. Finally, the models can be applied to policies that would expand or contract the volume of international trade.

ROMER'S THEORY OF LONG-RUN GROWTH: KNOWLEDGE AS A FACTOR OF PRODUCTION

Paul Romer bases his theory of long-term economic growth on the accumulation of knowledge. He explicitly recognizes knowledge as a factor of production, including it with the usual inputs--labor and capital. That, by itself, is not very controversial; it reverses none of the neoclassical theory's conclusions. Romer's contribution is his finding that any technical knowledge discovered by a firm (and embodied in its products) will eventually benefit other firms, even those that do not engage in research and development (R&D). Therefore, firms benefit not only from the knowledge they generate but also from the total stock of knowledge available in the economy. Economists refer to this type of side effect as a spillover, or externality--an action taken by one firm that has an impact, in this case a beneficial impact, on the productivity of other firms.

The Early Models: Introducing Externalities

Romer's early models are fairly abstract. He assumed, for example, that the growth of the body of technical knowledge was directly related to total investment in the economy.[1] He was then able to use the stock of physical capital as a proxy for the stock of knowledge, effectively transferring the spillover associated with knowledge to capital. He assumed that knowledge and physical capital were related because he observed a very high correlation between investment and output in the data--a much higher correlation than the neoclassical model would predict.

If the external effects associated with knowledge are large enough (and Romer assumed that they are), then the production function for the economy as a whole is no longer subject to decreasing returns to capital, and indeed, it displays increasing returns to scale. (Recall from the discussion of the neoclassical model that decreasing returns to capital means that successive additions to capital--with labor held constant--yield smaller and smaller increases to output. Increasing returns to scale means that doubling all inputs to production will more than double output). A rising rate of investment has the usual direct effect on output and an indirect effect (through the stock of knowledge) on the pace of technological change.

As Romer realized, the key to generating endogenous growth is to abolish a single characteristic of the neoclassical model: decreasing returns to capital. More generally, the characteristic shared by all endogenous growth models is nondecreasing returns to the factor that can be accumulated.[2] Physical and human capital are inputs that can be accumulated; firms can increase the available amounts with suitable investments. In contrast, "raw" labor cannot be accumulated; it can and does grow, but not because people are investing in it.[3] By ruling out decreasing returns, endogenous growth models prevent the return to, say, physical capital from being driven all the

1. See P.M. Romer, "Increasing Returns and Long-Run Growth," *Journal of Political Economy*, vol. 94, no. 5 (1986), pp. 1002-1037; P.M. Romer, "Capital Accumulation in the Theory of Long-Run Growth," in R.J. Barro, ed., *Modern Business Cycle Theory* (Cambridge, Mass.: Harvard University Press, 1989); and P.M. Romer, "Crazy Explanations for the Productivity Slowdown," in Stanley Fischer, ed., *NBER Macroeconomics Annual: 1987* (Cambridge, Mass.: MIT Press, 1987), pp. 163-202. For an earlier example of this type of model, see K.J. Arrow, "The Economic Implications of Learning by Doing," *Review of Economic Studies*, vol. 29 (June 1962), pp. 155-173.

2. Xavier Sala-i-Martin, "Lecture Notes on Economic Growth (I) and (II)," Working Papers No. 3563 and No. 3564 (National Bureau of Economic Research, Cambridge, Mass., 1990).

3. A growing literature examines the link between economic growth and fertility. See, for example, G.S. Becker, K.M. Murphy, and R. Tamura, "Human Capital, Fertility, and Economic Growth," *Journal of Political Economy*, vol. 98, no. 5, pt. 2 (October 1990), pp. S12-S37 and the references cited within.

way down to its cost. As a result, investment always remains profitable, which leads to continuous growth in the amount of capital available to each worker and in output per worker.

Romer also assumed that any one firm was so small relative to the overall economy that its investment decisions would have no effect on the total stock of capital or knowledge. The firm would therefore take no account of the second-round effects of its investment decisions on technological progress but would instead maximize profits through its choice of labor and capital, taking the total stock of knowledge as given. Under these conditions, the production function for an individual firm displays decreasing returns to capital and constant returns to scale, as in the neoclassical model; but the production function for the overall economy displays increasing returns to scale.

The most important contribution in Romer's early work was proving that the economy he described would reach a competitive equilibrium that would sustain perpetual growth in per capita output without relying on exogenous technological change. But the presence of an externality implies that market forces will not encourage the socially optimal amount of knowledge to accumulate in his framework. When companies form their plans for investment, they care only about the expected payoff to their own profitability; they ignore the spillover of benefits associated with their technical advances. Thus, from a social perspective, each firm will engage in "too little" investment. An omniscient social planner could improve societal welfare with the appropriate set of subsidies for investment.

Later Refinements: Innovation as the Source of Productivity Growth

Romer has subsequently refined his ideas about the accumulation of knowledge and its role as a driver of long-run growth. His early work saw the accumulation of physical capital and knowledge as strong complements, with growth in knowledge flowing from investment in capital goods: firms invest in capital goods because they improve productivity directly; any indirect effect on the stock of technical knowledge is a positive side effect of which the firm takes no account. In his more recent work, Romer shifts his emphasis to explain why firms invest directly in technical knowledge by undertaking research and development.[4]

4. See P.M. Romer, "Endogenous Technological Change," *Journal of Political Economy*, vol. 98, no. 5, pt. 2 (October 1990), pp. S71-S102; and P.M. Romer, "Capital, Labor, and Productivity," *Brookings Papers on Economic Activity: Microeconomics* (1990), pp. 337-367.

Romer sought to explain why private, profit-maximizing firms would produce technical knowledge through R&D even though such knowledge displays many characteristics of public goods.[5] Like public goods, such as national defense or interstate highways, technical knowledge can be used by an unlimited number of people at the same time. A public good is also "nonexcludable," meaning that its owner cannot preclude others from using it. Romer argues that knowledge is, at best, only partially excludable. A firm that builds a better mousetrap will not be able to prevent others from taking advantage of its new design forever. Even if patents prevent competitors from using the design itself, other firms will benefit from any new technology embodied in it.

In Romer's setup, profit-maximizing firms will undertake R&D even though they know that any inventions they develop will eventually benefit all firms in their industry. A new design is essentially costless to reproduce for sale or use within the firm. Firms can then sell the design (or the goods produced using it) at a price that exceeds the cost of production, thus recouping their investment in R&D. Basically, the innovation gives the firm a degree of monopoly power that allows it to charge a price greater than the marginal cost. Romer assumes that patents will completely protect these monopoly profits, allowing them to persist indefinitely. In more realistic extensions to his theory, however, other firms would be able to take advantage of the new technical knowledge, eliminating the innovating firm's monopoly profits by producing goods that are similar or more advanced.[6] That erosion of the firm's profits would spur further innovation.

The development and marketing of the Lotus Corporation's 1-2-3 spreadsheet program illustrates how innovation can spawn further innovation. The funds Lotus spent to develop 1-2-3 were fixed costs of production because they did not depend on how many copies of the program Lotus planned to manufacture. Once the program was written, additional copies of it could be produced at trivial cost (floppy disks are cheap). The software proved to be wildly popular, allowing Lotus to charge a price well above the marginal cost of production. Eventually, other companies introduced spreadsheet programs that were nearly identical to 1-2-3. The competing programs cut into Lotus's

5. This section draws from P.M. Romer, "Are Nonconvexities Important for Understanding Growth?" *American Economic Review*, vol. 80, no. 2 (May 1990), pp. 97-103.

6. See P. Aghion and P. Howitt, "A Model of Growth Through Creative Destruction," *Econometrica*, vol. 60 (1992), pp. 323-351; G.M. Grossman and E. Helpman, "Quality Ladders and Product Cycles," *Quarterly Journal of Economics*, vol. 106, no. 2 (May 1991), pp. 557-586; or G.M. Grossman and E. Helpman, *Innovation and Growth in the Global Economy* (Cambridge, Mass.: MIT Press, 1991).

market share and profitability, encouraging Lotus to develop new products that it hopes will repeat the success of 1-2-3.

Increasing returns to scale still play a role in Romer's framework. Because knowledge can be used by many people at the same time, the production function for an individual firm displays increasing returns to scale. Consider a firm that each year produces goods worth $10 million using one factory, 10 workers, and a certain amount of technical knowledge. This firm could produce goods worth $20 million by building a second plant, hiring 10 more workers, and using the same amount of knowledge. Since output has doubled with a less-than-doubling of the inputs, output would more than double if all of the inputs were doubled. Thus, production is characterized by increasing returns to scale.

As in his earlier models, Romer assumes that spillovers are a central feature of the economy. They occur both in the R&D sector, where a larger stock of knowledge raises the productivity of researchers engaged in R&D, and in the final output sector, where production benefits from a wider range of capital goods. Romer's later model displays constant returns to the accumulation of knowledge--the return on investment in R&D does not fall as the stock of knowledge increases. The resulting equilibrium features endogenous growth in per capita output, driven by the continuous introduction of new products and advances in technology.

In this framework, a new design enables a firm to produce a new good and increases the overall stock of knowledge, which lowers costs for R&D and final output. The crucial assumption for endogenous growth is that the positive effect of increased knowledge on productivity does not weaken as the stock of knowledge grows. If it did--perhaps as science approached a technological frontier--endogenous growth would taper off, and the model would resemble the neoclassical model. Romer notes that this feature makes endogenous growth more an assumption of the model than a result.

Policy Implications

Three important policy prescriptions flow from Romer's theory. The first is the same as that suggested by the neoclassical model--a reduction in the federal deficit. Lowering the deficit would raise the rate of national saving, lower interest rates, and speed growth in Romer's model. Lower interest rates increase the amount of human capital devoted to R&D by raising the discounted value of any given stream of future revenues associated with a new design. More research translates into a permanent increase in the economy's rate of growth.

The second policy prescription is subsidies for R&D. The accumulation of knowledge drives growth in Romer's theory, but because R&D benefits firms other than the innovator, too few resources are devoted to it. Therefore, it is not only possible but desirable for government to influence economic growth in Romer's theoretical framework--specifically, by subsidizing basic research. Failing that, subsidies for educating and training workers (the most important factor in developing technical knowledge) would be the next best policy.[7]

Third, Romer's work suggests several channels through which economies might benefit from expanded international trade.[8] Trade should spur growth by providing researchers with greater incentives to provide new designs: a firm that invents a new product will have access to a larger market (and greater monopoly profits) if the economy is open to trade. Trade also expands the stock of knowledge available to those engaged in R&D by exposing them to more goods produced using the latest designs. Researchers can raise their productivity by learning from new goods produced abroad. In addition, international trade helps prevent the duplication of research efforts across countries. Freer trade implies that the fixed costs associated with developing a new design need to be incurred only once. Human capital is released from reinventing the wheel.

OTHER MODELS OF ENDOGENOUS GROWTH

Numerous theoretical papers have appeared recently in the literature on endogenous growth. The defining characteristic of these theories is that they generate perpetual growth in per capita output without relying on exogenous forces. They each do this in the same basic fashion as Romer's model: by overturning the assumption of decreasing returns. The literature survey that

7. In Romer's latest models (in contrast to his earlier work), subsidies for the accumulation of physical capital may or may not raise growth. See Romer, "Endogenous Technological Change."

8. The most complete exposition of the effects of trade liberalization in Romer's model can be found in L.A. Rivera-Batiz and P.M. Romer, "Economic Integration and Endogenous Growth," *Quarterly Journal of Economics*, vol. 106, no. 2 (May 1991), pp. 531-556.

follows is not exhaustive, but it covers the range of available results and policy prescriptions.[9]

Human Capital in Models of Endogenous Growth

As the primary input used in research and development, human capital plays an important role in models such as Romer's 1990 model, in which endogenous growth results from endogenous technical change. Human capital also plays a prominent role in other models of endogenous growth. Robert Lucas outlines two such models: one involves spillovers from the investment people make in formal education, and the other features productivity growth driven by on-the-job training (learning by doing).[10] In both models, Lucas interprets human capital as the overall level of skill available in the economy.

In the first model, Lucas assumes that society builds human capital by investing in it: workers postpone immediate consumption (by going to college instead of working) in the hope of improving their prospects for consumption (getting a job with higher wages after graduation). However, merely allowing for investment in human capital is not sufficient to support endogenous growth. Lucas also assumes that there is an externality (or side effect) associated with human capital: the productivity of all workers--even those who receive no formal training--benefits from an increase in the general skill level of the overall economy. Lucas made this observation when he noticed that groups of firms producing roughly the same products tend to cluster in the same geographic location, usually a city. He reasoned that firms do this because they benefit from being close to other firms that do similar work. This phenomenon explains why Manhattan has a garment district, a financial district, an advertising district, and so on. Those districts are intellectual centers where ideas are exchanged, either explicitly or implicitly.

Lucas's formulation is very similar to Romer's early model, in which the externality was associated with the accumulation of physical rather than

9. For other surveys of this literature, see the symposium on new growth theory in *Journal of Economic Perspectives*, vol. 8, no. 1 (Winter 1994), pp. 3-72; D.M. Gould and R.J. Ruffin, "What Determines Economic Growth?" *Economic Review*, Federal Reserve Bank of Dallas (Second Quarter 1993), pp. 25-40; or U.S. International Trade Commission, "The Dynamic Effects of Trade Liberalization: A Survey," USITC Publication 2608 (February 1993).

10. R.E. Lucas, "On the Mechanics of Economic Development," *Journal of Monetary Economics*, vol. 22 (1988), pp. 3-42.

human capital.[11] If the externality is large enough, then endogenous growth occurs in the presence of decreasing returns because the incentive to invest in human capital does not diminish as the stock of human capital grows. Under these circumstances, human capital can continue to accumulate indefinitely. However, people invest less in human capital than is socially optimal because they ignore the beneficial spillover associated with their investment. Therefore, Lucas's model suggests that living standards could be raised with a scheme to encourage workers to improve their education and skills.

Lucas notes that this model is consistent with international evidence on migration. If human capital has external effects, then workers in countries with high levels of human capital will be more productive and earn higher wages than those in countries with low levels. Workers in poorer countries, which will have lower levels of human and physical capital, thus have an incentive to migrate to richer countries. Since countries with larger stocks of human capital can remain permanently richer, there is no force for convergence in Lucas's model, and the incentive to migrate can persist indefinitely.

Lucas's second model starts from the premise that workers accumulate human capital through on-the-job training rather than through investments in formal education.[12] In this model, workers accumulate human capital not by withdrawing from the labor force to go to school but by acquiring new skills as they learn to produce an ever-growing range of goods. As long as new goods are continually introduced (and especially if they become more technologically advanced), the stock of human capital will grow, driving growth of per capita output as well. Lucas's framework is not complete because he does not model the factors that cause new goods to be introduced; instead, he assumes that they do.

The experience of the newly industrialized countries (NICs) of eastern Asia suggests that learning by doing is more relevant for the study of long-run growth than is formal education. Lucas argues that the "growth miracles" these countries have experienced since World War II cannot be attributed to formal learning, because changing the level of average education rapidly for an entire nation is difficult. However, he did notice a correlation between the countries that grew the fastest and those that experienced rapid structural

11. See Romer, "Increasing Returns and Long-Run Growth."

12. For examples of similar models, see Alwyn Young, "Learning by Doing and the Dynamic Effects of International Trade," *Quarterly Journal of Economics*, vol. 106, no. 2 (May 1991), pp. 369-405; or Nancy L. Stokey, "Learning by Doing and the Introduction of New Goods," *Journal of Political Economy*, vol. 96, no. 4 (August 1988), pp. 701-717.

change. Lucas asserts that rapid structural change, supported by aggressive export-oriented policies, enabled the NICs to accumulate human capital rapidly through on-the-job training. A focus on exports is important because it allows the mix of goods produced by firms to change more rapidly than the mix of goods desired by domestic consumers.

The Link Between International Trade and Long-Run Growth

Studies that draw on the neoclassical tradition--Solow's basic model assumed closed economies--have difficulty demonstrating a relationship between an economy's growth rate and its degree of openness to trade. In these models, opening an economy to trade will generate a one-time increase in the level of output that results from the reallocation of resources according to comparative advantage. Yet empirical results from the development literature indicate that countries that are open to trade seem to grow faster than those that do not have liberal trade policies. Some models of endogenous growth point to a possible link between trade and growth.

Gene Grossman and Elhanan Helpman outline a mechanism by which trade liberalization can stimulate growth: opening an economy to trade may increase the incentive to innovate by providing entrepreneurs with a larger market for their inventions.[13] Moreover, developing countries can imitate the innovating country by producing close substitutes, which will eventually eliminate the monopoly profits accruing to the innovator. Such imitation will foster technological progress in the follower country and encourage the leading country to innovate further, spurring more inventions and more monopoly profits.

In addition, Grossman and Helpman show that trade policies, such as tariffs or export subsidies, can have important effects on the allocation of resources within a country.[14] They employ models that share many features with those of Paul Romer; in particular, growth is driven by innovation that results from investments in R&D made by private, profit-maximizing firms. However, they add a second production sector and a foreign country to

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13. G.M. Grossman and E. Helpman, "Trade, Innovation, and Growth," *American Economic Review*, vol. 80, no. 2 (May 1990), pp. 86-91.

14. See, for example, G.M. Grossman and E. Helpman, "Growth and Welfare in a Small, Open Economy," in E. Helpman and A. Razin, eds., *International Trade and Trade Policy* (Cambridge, Mass.: MIT Press, 1991); Grossman and Helpman, "Quality Ladders and Product Cycles"; G.M. Grossman and E. Helpman, "Comparative Advantage and Long-Run Growth," *American Economic Review*, vol. 80, no. 4 (September 1990), pp. 796-815; or G.M. Grossman and E. Helpman, "Trade, Knowledge Spillovers, and Growth," Working Paper No. 3485 (National Bureau of Economic Research, Cambridge, Mass., October 1990).

Romer's basic framework. In such models, a country that protects a sector that competes with the R&D sector for resources risks lowering its rate of economic growth. Returns to factors of production rise in the protected sector, drawing resources (for example, human capital) out of the R&D sector, thereby slowing innovation and growth.

Grossman and Helpman also show that the effects of trade policies depend on the worldwide pattern of comparative advantage. For example, in Romer's model a subsidy to R&D will speed a country's rate of growth. When Grossman and Helpman extend the model to include a foreign economy, they find that a subsidy to R&D will speed growth only if it is undertaken by countries that have a comparative advantage in R&D. If a country with a comparative disadvantage in R&D subsidizes it (or if international patterns of trade change drastically as a result of the policy action), the subsidy may slow growth.

The specific results of each of Grossman and Helpman's models are not as important as the fundamental lesson embodied in their papers: the effects of trade policies on economic growth will depend on patterns of comparative advantage and on the allocation of resources both at home and abroad. Their work illustrates the hazards of drawing facile conclusions about the benefits of international trade from endogenous growth models. They show that under certain plausible circumstances, a country's rate of growth may fall when it joins the world trading system. Growth would drop if the country had a comparative advantage in R&D and if liberalizing trade led to a shift in demand toward consumption goods. The resulting increase in demand for inputs to produce those goods could draw resources away from R&D and into production, slowing innovation and growth.

Endogenous Growth in the Presence of Constant Returns to Scale

In a standard production function that includes more than one input, assuming nondecreasing returns to one input (as many endogenous growth models do) implies assuming increasing returns to scale. However, increasing returns to scale are not required to generate endogenous growth. Sergio Rebelo stripped endogenous growth down to its barest essentials by devising a model in which production of goods and services displays constant returns to scale.[15] Rebelo assumes that output is produced with one factor input--the

15. S. Rebelo, "Long-Run Policy Analysis and Long-Run Growth," *Journal of Political Economy*, vol. 99, no. 3 (1991), pp. 500-521. For a related model, see L.E. Jones and R. Manuelli, "A Convex Model of Equilibrium Growth: Theory and Policy Implications," *Journal of Political Economy*, vol. 98, no. 5, pt. 1 (October 1990), pp. 1008-1038.

stock of capital, albeit broadly defined to include both physical and human capital. Under this setup, the return from successive investments in capital always remains constant, regardless of the size of the existing stock. As long as this return is greater than the cost of capital, it will always be profitable for firms to invest, and perpetual growth in per capita output will result.

Rebelo's model has two important implications. First, it is possible to generate endogenous growth with constant returns to scale in production, although doing so requires a highly abstract model. Second, the model demonstrates that government tax policy can influence an economy's rate of growth in the long run. In this model, a tax on capital income reduces the after-tax rate of return on investment in capital, thereby diminishing the incentive to invest and lowering the rate of growth. A tax on consumption, in contrast, does not affect the long-run rate of growth; rather, it merely lowers the level of per capita consumption. An income tax, which affects both consumption and investment at the same rate, will do a little of both: it will lower consumption and reduce the rate of growth in the long run.

Fiscal Policy in a Model of Endogenous Growth

Robert Barro makes explicit the effects of government action on the growth rate by introducing a public sector into a simple Rebelo-type model of endogenous growth. Barro assumes that production of private goods and services depends on private capital (broadly defined to include human capital) and on a flow of services from government spending on services that improve private productivity, such as law enforcement, national defense, infrastructure, and so on.[16] The model features decreasing returns to private capital and constant returns to scale (that is, with respect to both physical and human capital). Under those conditions, the private return on investment will not fall as the economy expands as long as government spending rises in tandem with private investment. Growth will continue as long as the government spends a constant proportion of national income on productive government services. If so, then an investment in private capital will cause aggregate income to rise, leading the government to increase its spending, which in turn raises income further.

Barro shows that his model has an optimal ratio of government spending to output, given reasonable values for the model's parameters. If the

16. See R.J. Barro, "Government Spending in a Simple Model of Endogenous Growth," *Journal of Political Economy*, vol. 98, no. 5, pt. 2 (October 1990), pp. S103-S125. For a broader survey of government policy in models of endogenous growth, see R.J. Barro and X. Sala-i-Martin, "Public Finance in Models of Endogenous Growth," *Review of Economic Studies*, vol. 59 (1992), pp. 645-661.

economy is below the optimal ratio, increases in the share of government spending will speed growth; once the optimal ratio has been reached, however, further increases in government spending will reduce the rate of growth. This theory holds only for spending that improves the productivity of private firms. If the government uses part of tax receipts on its own consumption (that is, goods and services that do not benefit private productivity), then growth will be lower than if the government uses all tax receipts for productive spending. Growth slows because the extra spending raises the tax rate without affecting private productivity. People will have less incentive to save and invest because their after-tax rate of return on investment will be lower. Barro provides some empirical support for the idea that increased spending for government consumption lowers the equilibrium rate of growth.

The equilibrium in Barro's model leaves some room for intervention by the government to raise living standards. When private firms make capital investments, they do not account for the fact that such investments will generate additional income (and tax revenue) that will be used for productive government spending, which benefits all firms. Because they ignore this external benefit, private firms tend to invest too little in physical capital. A government intervention that corrects this externality would produce a higher rate of economic growth.

Convergence in a Model of Endogenous Growth

Robert Tamura demonstrates that endogenous growth and convergence can coexist in a single model.[17] He does that by pursuing the simple notion that an idea is more difficult to discover than it is to learn. Convergence of output in Tamura's framework results from convergence in levels of human capital, which occurs because the payoff from additional learning is higher for individuals with low levels of education. A person at the technological frontier must discover new knowledge, so advances are hard to achieve. People whose education and skills are below average can acquire existing knowledge, which is easier to do.

Production of goods and services in Tamura's model is quite similar to that in Rebelo's, featuring a single input (human capital) and constant returns to scale. Tamura, however, assumes that a spillover is associated with human capital in that the level of human capital throughout society has a positive impact on each person's accumulation of human capital. Specifically, he

17. R. Tamura, "Income Convergence in an Endogenous Growth Model," *Journal of Political Economy*, vol. 99, no. 3 (1991), pp. 522-540.

assumes that people with below-average skills and knowledge have a higher rate of return on their investments in human capital than do individuals with above-average levels. Because they have a larger incentive to invest in human capital, people whose skills and knowledge are below average accumulate it faster than people with higher levels. This force causes convergence. Tamura's results apply to countries as well as individuals if the spillover he describes operates across national boundaries.

CONCLUSION

The literature on endogenous growth includes a wide range of models and yields a variety of policy prescriptions. The theoretical models suggest various channels through which countries can spur growth in the long run: they can increase their rates of national saving, lower tax rates on capital income, subsidize human capital or R&D, increase productive government spending, and lower trade barriers.

The theoretical models described above are very abstract, so their predictions about the effects of policy changes should be taken with caution. The analysts who developed the models make many simplifying assumptions so that they can solve the models and focus on specific sources of growth. However, predicting the effects of policy changes in the real world may not be so straightforward.[18] For example, the models typically assume that governments will finance subsidies with lump-sum taxes, which introduce minimal distortions into the economy's pattern of incentives and allocation of resources. Few examples of lump-sum taxes exist; one well-known example was Britain's poll tax, which was a political disaster. Thus, subsidies must in practice be financed using a more distortionary tax (for example, a progressive income tax), which may partially offset the benefits.

Another problem is that these abstract models tend to yield nonspecific policy prescriptions. For example, it is difficult to turn the general dictum to "subsidize human capital" into a specific policy that would encourage investment in education or training. The policy prescription presumes that the government knows which forms of human capital have spillovers associated with them and which do not.

18. This section draws from C.I. Plosser, "The Search for Growth," in *Policies for Long-Run Economic Growth*, a Symposium Sponsored by the Federal Reserve Bank of Kansas City, Jackson Hole, Wyo., August 27-29, 1992 (Kansas City, Mo.: Federal Reserve Bank of Kansas City, 1992).

In addition, the policies that emerge from the endogenous growth models are qualitatively similar to those that would flow from the neoclassical model. The difference is that the new models predict that such policies will affect the rate of growth permanently, whereas the neoclassical model predicts that the effect on growth tapers off as the economy approaches a new steady state. This quantitative difference is important. For example, the neoclassical model predicts that a government policy that encouraged a permanent 10 percent increase in the national saving rate could be expected to raise per capita output by roughly 5 percent after several decades. In contrast, some endogenous growth models imply a much greater gain--perhaps as high as 10 percent or 15 percent--and one that keeps growing.